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THE INFLUENCE OF STOCK RECORD ERRORS

ON INVENTORY SYSTEM OPERATIONS

by

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ABSTRACT:

Inventory record errors can and do adversely affect supply operations. However, the extent and seriousness of the effects of errors on inventory system operations has not been known. Proposals to reduce stock record errors cannot be properly evaluated until the "costs" of operating with inaccurate records is determined. This study develops a means of determining the effects of errors on inventory system operations.

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1. Introduction to the Problem

It has been asserted that some of the most successful applications of operations research techniques have been in the field of inventory control. Generally, the problem formulations have as their objective the derivation of decision rules to determine when to buy stock and how much to buy for the various items in the inventory. The resulting decision rules are applied to the inventory through inventory records. For example, in the rule "down to four, order more," we mean that when our actual on-hand inventory falls to a quantity of four, we should reorder. In practice we generally do not check the physical quantity on-hand before reordering; rather, we maintain records of inventory quantities and reorder when our records indicate that we are "down to four." An inventory manager hopes that there is good correspondence between the state of affairs implied by his records and the physical state of affairs in the warehouses. If this is not the case, predictions of effectiveness may be invalid. Throughout this paper we use the term inventory record error or discrepancy to mean the non-agreement of the quantity of an item shown in the appropriate stock record to be available for issue with the quantity in the warehouse actually available for issue. Positive inventory record errors have been defined as those where the actual on-hand quantity exceeds the record quantity; similarly, negative errors describe a condition where there is less material available for issue than the records indicate (1). We use this convention.

Discrepancies are generated in inventory records through actions which cause changes in the physical quantity of material and those actions which cause changes in the record on-hand quantity. In particular, discrepancies are introduced in the processes of receiving and issuing material, as well as by unauthorized removals of material or unposted receipts of material. Additionally, discrepancies may be generated in adjustments of records for various reasons including, conspicuously, those resulting from the physical inventory process.

Discrepancies are discovered in the physical inventory process, as well as by the occurrence of a warehouse refusal which triggers a spot physical inventory. Other notification of discrepancies may take place through stock location audit efforts.

The presence of errors in inventory records diminishes supply effectiveness. A positive error in the record of an item will cause a reorder to be placed for the item in question too soon. Too soon means that the reorder will be placed before the reorder point is actually reached. If the system is not aware of a positive discrepancy, it may needlessly backorder material. Thus, positive errors tend to increase the value of inventory carried, without increasing the effectiveness attained on an item. Negative errors result in greater risk of stockout than is believed to exist, because an item with an undetected negative stock record error will not be reordered until the reorder point has been exceeded by the amount of the error. Negative errors may give rise to warehouse refusals which require exceptional treatment in the processing system and cause delays in servicing the customer.

These effects are especially serious in the case of severe constraints on procurement budgets and long lead times for material. In such circumstances, the spending of money in buying stock for an item with a positive error may result in an insufficiency of funds to reorder an item which has legitimately reached its reorder point, at some time in the future. Long lead times may result in lengthy stock-out periods when negative errors are present, even if procurement funds are available.

For some time the General Accounting Office has expressed concern with the ability of the armed forces to account for inventories of materials (2). Increasing concern has also been exhibited for the impact of stock record errors on the ability of the U. S. Navy stock points to perform their fleet support mission (3). In February, 1968, the Naval Supply Systems Command (NAVSUP) elevated the inventory record accuracy problem to a position of first priority on the "Tough Ten" list of management problems facing the command.

The inventory record accuracy problem may be studied from a number of viewpoints. Of course NAVSUP is vitally concerned with improving record accuracy and doing so in an efficient manner. NAVSUP also recognizes that having completely accurate records is not a realistic goal. The level of accuracy to which they should strive, the inventory record accuracy goal, has not been well specified, however.

We think that an important insight into record accuracy may be gained by thinking about the problem in terms of costs and benefits. There is a cost associated with any given level of record accuracy. This cost represents audit, quality assurance, data-scrubbing, and physical inventory efforts associated with maintaining records at a given level of accuracy. The question of how much expense to incur on behalf of record accuracy can only be answered in terms of the benefits derived from record accuracy.

As stated earlier, inventory record errors adversely affect supply effectiveness. The benefits of more accurate records are then improvements in supply effectiveness. In this study, our objective is to quantify the effects of inventory record errors on supply operations.

2. System Description and Model

The vast majority of the items stocked in the Navy supply system (outside of Defense Supply Agency items) are managed by three Inventory Control Points (ICP), one each for ships parts, aeronautical equipment, and electronics. The ICP's maintain stock records on the items they manage, and make all procurement decisions. The inventory exists physically at stock points which maintain a transaction reporting data link with the ICP's. Because of the transaction reporting capability of the system, the ICP's use continuous review, reorder point-reorder quantity inventory policies. The procurement budget, allocated annually, is the primary constraint on the ICP inventory policies. Within an ICP, items are segregated into material cognizance classes (cogs) and procurement budgets are allocated by cog. The procurement budget determines (in a manner which we need not go into here) the individual item reorder points and reorder quantities, and thus, the theoretical maximum level of supply effectiveness that will be achieved.

Over at least the last five years, procurement budgets have been quite restrictive so that items within a cog compete with one another for the available procurement dollars. Under such conditions, study of a multi-item inventory must explicitly recognize dependence between individual items. The presence of dependence between items makes the analytical study of record errors most difficult. A Monte Carlo simulation program offered the easiest way to approach the problem.

A description of the relevant parts of the supply system was reduced to a FORTRAN IV language computer program. The program simulates operations one day at a time and prints reports at specified intervals. Its modular construction permits the use of a variety of demand generators, lead-time distribution assumptions, budget computation and availability procedures, ordering decision rules, as well as the rate and variety of discrepancy generation. For the study being conducted, each stock record carries two on-hand quantity data fields; one contains the recorded quantity, while the other holds the actual quantity on hand.

Reorder actions are based upon the recorded quantities. Requisition arrivals initiate issue action only when the "records" indicate that stock is on hand. The quantity issued, however, cannot exceed the actual on-hand quantity. The simulation employs two pseudorandom number generators; one for demand generation and the other for all other Monte Carlo requirements. Program control was accomplished with a combination of a modified event-store control on requisition processing, storing only the time of the next requisition arrival in each stock record, and a time-step control on receipt processing.

The supply system we have chosen to model operates on an issue preposting system so that material is not issued from stock unless the records indicate that material is available for issue. This system is prevalent at stock points of the U. S. Navy and is in contrast to a postposting system in which issues are posted to stock records subsequent to the physical issue of material. We treat receipts as being posted and made physically available for issue at the same time. All shortages are backordered.

Demands (simulated requisitions) are generated in accordance with a "stuttering Poisson" stochastic process; that is, the time between requisition arrivals is distributed as an exponentially distributed random variable, while the quantity demanded on an individual requisition is distributed as a geometrically distributed random variable.

During the daily processing routine, the day's receipts are batch-posted at the beginning of each day. Next, backorders are released for those items having stock on hand. Finally, each item is sequentially examined to determine whether any demands will be received on the current date. If so, all such requests are processed in turn. Spot inventories are conducted when there is a warehouse refusal, which occurs when the actual on-hand quantity is less than the attempted issue quantity. Whenever the budget permits and the inventory position, defined as the sum of record on-hand quantity

and quantity on order minus the sum of the quantity currently being demanded and the quantity backordered, does not exceed the reorder point, an order is placed for the smallest multiple of the reorder quantity that causes the inventory position to exceed the reorder point. The lead times for reorder material are assumed to be random variables, normally distributed with standard deviation equal to .29 times the mean lead time. Lead times are truncated, in any case, to be not less than one day or more than 2.74 times the mean lead time. If there are insufficient uncommitted funds in the procurement budget to provide for an order, no order is placed. Additionally, on the first day of each year, after the new budget has been received, each stock record is scanned and reorders are placed in multiples of the item reorder quantity as needed to raise the inventory position above the reorder point, provided the new budget so permits.

Discrepancies are introduced by Monte Carlo mechanisms in the processes of issuing and receiving material. Initially, all records agree with the actual situation. Whenever material is received, a pseudorandum number is generated. The value of this number determines first of all if the quantity actually received is greater than, or less than, the quantity ordered by a specified percentage; the resulting quantity thus computed to be physically received is truncated to an integer value and posted accurately to the actual on-hand field of the item record. The quantity thought to have been received is posted to the item record on-hand quantity field. If the correct quantity was received, the random number determines whether it is posted accurately to the record on-hand quantity field. Provision is made for posting the correct quantity to an incorrect record, determined at random by the value of a random number. The relative frequency of each of these occurrences as well as the percentage deviations of a quantity received are controlled through parameters which remain fixed throughout each run. The same set of parameters governs such events for all items in the inventory.

Somewhat similarly, in the issue process a randum number determines whether the correct quantity is issued, whether nothing is actually issued or whether the quantity issued varies from the requisition quantity by various amounts of either underissue or overissue. Again, relative magnitudes and relative frequencies are determined by system parameters which are held fixed over a run.

The discovery of an inaccurate record will be made if there is a warehouse refusal. As is customary Navy practice, a warehouse refusal triggers a "spot" inventory of the item in question. In the spot inventory process, a random number determines whether the spot inventory being conducted results in the record on-hand quantity being set equal to the actual on-hand quantity or whether the discrepancy remains unaffected by the spot inventory.

Statistics are accumulated on unit-days backordered, requisition-fill effectiveness, unit-days stock held, number of procurement order initiated, number of receipts processed, number of spot inventories taken, number of warehouse refusals, number of discrepancies generated or corrected in the processes of issuing, receiving or inventorying, and value of stock procurements.

3. Data and Experiments

The experiments to be described were run using a population of 100 items. The items used were those members of the 1H cog at the Ships Parts Control Center calculated to place the greatest obligations on the 1H cog procurement budget in the year beginning September, 1967.* For each item, unit cost, estimated procurement lead time, asset position, estimated mean annual demand, estimated variance of annual demand, reorder point, and reorder quantity information was obtained and used in the simulation. The two parameters needed to describe the stuttering Poisson demand process for each item were determined from the demand mean and variance and lead time data.

From asset position, demand, reorder point, and reorder quantity information the expected cost of funding these items over a one-year period was calculated. Eighty percent of this amount was arbitrarily selected as the procurement budget for the simulation. This budget insures that the procurement budget is an active constraint.

Data on discrepancy introduction to item stock records was obtained from a special study conducted by personnel of the Quality Assurance and Internal Review Department at the Naval Supply Center Oakland. The parameters used in the Monte Carlo introduction and correction of errors were as follows:

EVENT	PROBABILITY
Receipt is 6% less than documented	0.015
Receipt is 8% more than documented	0.015
Receipt posted to randomly selected record	0.010
Receipt processed correctly	0.960
Issue processed correctly	0.980
Failed to issue	0.007

* These items were not typical in the sense that they have high demand rates and/or substantial unit costs.

EVENT (cont.)	PROBABILITY
Overissue	0.007
Overissue by 8%	0.660
Overissue by 18%	0.250
Overissue by 40%	0.090
Underissue	0.006
Underissue by 6%	0.660
Underissue by 20%	0.170
Underissue by 60%	0.170
Spot Inventory corrects discrepancy	0.970
Spot Inventory does not correct discrepancy	0.030

Two experiments were performed. In experiment I, the history of the 100-item inventory was simulated for a five-year period. Only spot inventories, resulting from warehouse refusals, were conducted during the five years. The purpose of the experiment was to determine the growth of record error, measured as the percent of the item records in which the recorded on-hand quantity did not agree with the actual on-hand quantity, over time. Run IA, a "clean" run was run with all issue and receipt processing functions performed perfectly. Operations of the system during this run was influenced, however, by the procurement budget constraint. The clean run, IA, provided a yardstick against which to judge the results of run IB, which was run with errors being introduced at the rates experienced at NSC Oakland.

The purpose of the second experiment was to determine the effect of a perfectly conducted, annual, complete physical inventory. Two years of system history were simulated. Run IIA was the clean run. Run IIB was the two-year run in which there was no physical inventory conducted at the end of the first year. Run IIC was made with a complete, perfectly conducted, physical inventory at the end of the first year.

4. Results

The purpose of the experiments was to determine the influence of stock record errors on inventory operations. One measure of the effect of errors is the incremental cost of operations in the sense of classical inventory theory. These costs are the incremental ordering, holding, and backorder costs. However, operating measures may be more meaningful. The operating measures studied are: the number of requisitions filled completely, the number of requisitions filled at least partially, the number of warehouse refusals, the average inventory held, the average number of backorders, and the day on which the budget was exhausted. Additionally, the percent of records that were accurate at year's end is shown.

Table I summarizes the results of Experiment I with respect to operating measures. With respect to most performance measures, Run IB, the simulation run with errors, had lower or less desirable performance than the "clean" run. This was, of course, to be expected, but the magnitude of the degradation in performance due to errors was not predictable. The budget was always exhausted sooner in the error introducing runs IB since orders are placed too soon on items with positive error and are not balanced out by orders placed too late on items with negative errors. This is due to the fact that a certain number of negative error item records are discovered by warehouse refusal situations while positive errors are never discovered in the preposting system modeled.

The plot of the percent of accurate records as a function of time for Run IB is shown in Figure 1, along with the only other data of this form known to the authors. The other function in Figure 1 is from the Bayonne report.[1] In comparing the two functions, two facts must be kept in mind. The first is that the Bayonne study was based on randomly selected items, while the item population used in the simulation consists primarily of fast moving items. As error is introduced in issue and receipt processing, fast moving items experience a greater number of requisitions and receipts and, therefore, a greater

TABLE 1

SUMMARY RESULTS OF EXPERIMENT I (AVERAGE OF 3 REPLICATIONS)

Annual Summary Figures Measures		Actual Values Run IA	Performance Indices Run IA	Performance Indices Run IB
No. requisitions processed		2905	1.0	1.0
No. requisitions filled completely		1156	1.0	0.920
No. requisitions filled at least partially		1239	1.0	0.927
No. warehouse refusals		0.0	0.0	9.733
No. stock orders placed		465	1.0	0.944
Average actual inventory held		$962,721	1.0	1.016
Average number units backordered		108,894	1.0	1.041
Day budget exhausted	Year 1	319	1.0	.984
	Year 2	322	1.0	.956
	Year 3	314	1.0	.980
	Year 4	337	1.0	.934
	Year 5	305	1.0	.924
Percent records accurate at end of year				
	Year 1		100	80.3
	Year 2		100	65.7
	Year 3		100	54.3
	Year 4		100	47.3
	Year 5		100	42.0

NOTE: Performance indices used are the quotient of the average performance of the parameter set over the three replications divided by the performance of the error-free system if the latter is not zero; otherwise, the divisor is one.

number of errors are introduced. We would thus expect the simulated percent of records accurate curve to lie below the Bayonne function. This would be the case if it were not for the fact that the simulation started with all records accurate, while the Bayonne error curve begins with only 93% of the records accurate. The 7% record inaccuracy represents a so-called residual error, the error remaining in the records after a complete physical inventory. The other qualification to be kept in mind when comparing the two curves is that the Bayonne error curve was extrapolated to five years from data on the growth of error in the first half year after a physical inventory.

The average annual increment costs of Run IB over Run IA were as follows:

Incremental ordering costs at $42* per order	=	$ - 1,092
Increment holding costs at I = .15*	=	+ 2,336
Incremental shortage costs at $10* per shortage plus $0.01 per backorder day	=	+ 16,261
TOTAL		$17,505

The backorder cost of $0.01 is a conservative one; this amounts to a charge of $3.65 per unit backordered for one year. The total incremental cost, $17,505 annually for our sample of 100 items, is reasonably large and represents another indication of the magnitude of the inventory record accuracy problem.

In the second experiment we are primarily interested in the differences between Runs IIb and IIc. Run IIb was a two-year simulation with errors being introduced. Run IIc, like Run IIb, was made with errors being introduced, but a perfectly conducted, complete physical inventory was taken at the end of the first year. The operating performance measures are summarized in Table II.

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* These cost parameters were used by the Fleet Material Support Office in establishing the reorder point and order quantities for the items used in the simulation.

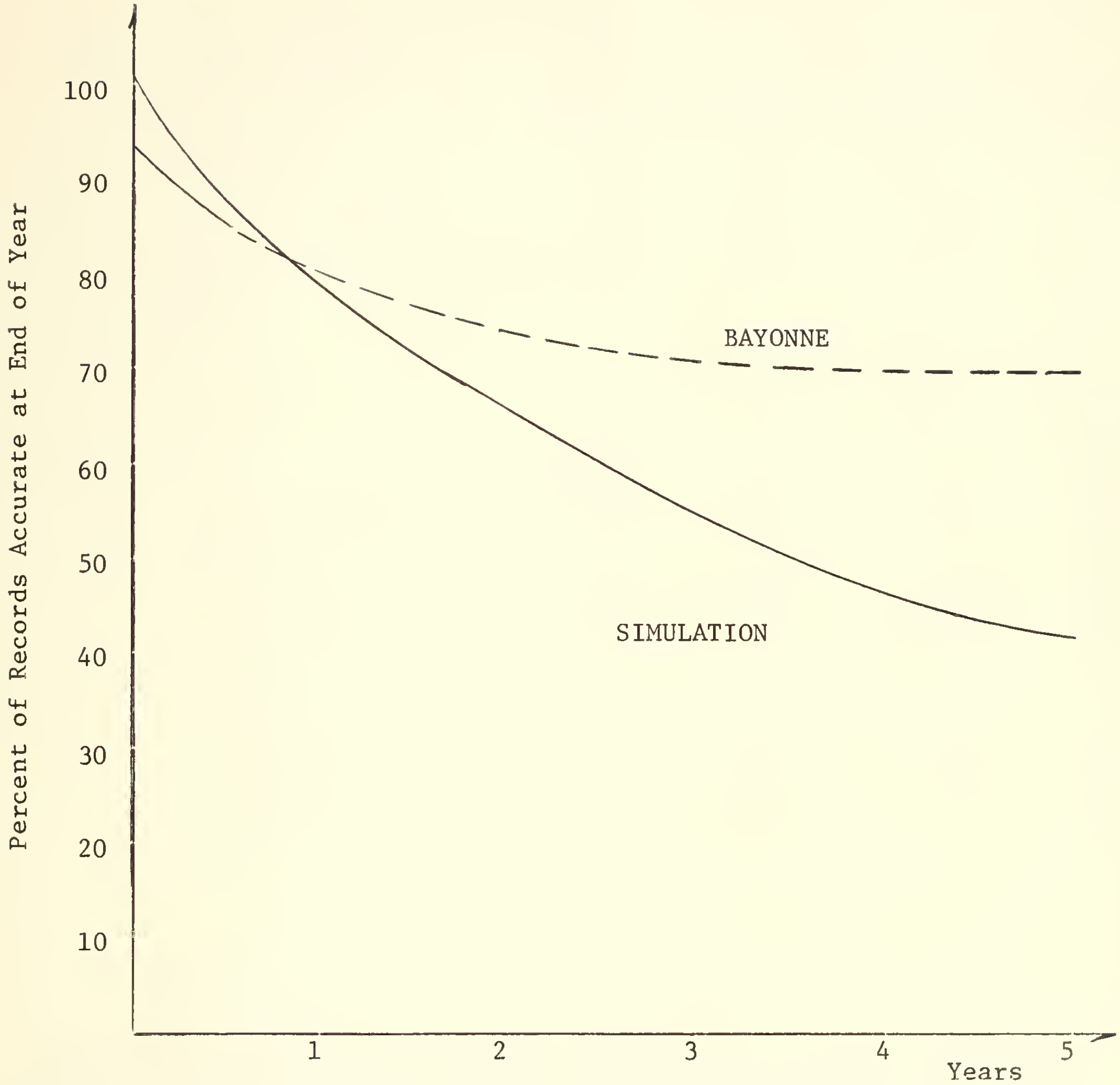

Figure 1. Percent of Records Accurate as A Function of the Time Since a Physical Inventory

The incremental cost of Run IIB over Run IIC is $10, 554 at $0. 01 per backorder day. The question of course arises as to whether or not a complete physical inventory of the 100 items could be conducted for less than $10, 554.

TABLE 2

SUMMARY RESULTS OF EXPERIMENT II (AVERAGE OF 3 REPLICATIONS)

Annual Summary Figures Measures		Actual Values Run IIA	Performance Indices Run IIA	 Run IIB	 Run IIC
No. requisitions processed		2910	1.0	1.0	1.0
No. requisitions filled completely		1314	1.0	.979	.977
No. requisitions filled at least partially		1393	1.0	.990	.988
No. warehouse refusals		0	0	14	12
No. stock orders placed		573	1.0	1.005	1.005
Average inventory held		1,262,290	1.0	.997	.997
Average number units backordered		89,092	1.0	1.056	1.045
Day budget exhausted	Year 1	316	1.0	.993	.993
	Year 2	322	1.0	.956	.993
Per cent records accurate at end					
of year	Year 1		100	80	80
	Year 2		100	67	78

NOTE: Performance indices used are the quotient of the average performance of the parameter set over the three replications divided by the performance of the error-free system if the latter is not zero; otherwise, the divisor is one.

5. Conclusion

Simulation offers an efficient means for studying many aspects of the inventory record accuracy problem. Analytic relationships of errors as a function of time and inventory system and item parameters have not been available. Simulation provides an easy means with which to study the growth and effects of errors in complex inventory systems. It also provides a means of evaluating inventory-taking schemes. The effects of NAVSUP's new policy of inventorying an item just prior to placing a reorder are currently being investigated through the simulation.

A point which seems to be important is that simply the number of records in error, or the percentage of the records which are inaccurate, is only the grossest kind of error measure. Record inaccuracy is important in so far as it influences supply operations. The simulation shows that the influence of errors on supply operations depends upon the type and magnitude of the individual errors and upon system characteristics such as preposting and an active procurement budget constraint. It has been demonstrated that the presence of stock record errors in an inventory system with many of the characteristics of the Navy supply system influences complete and partial fill rates, backorders, inventory held, ordering rates, and the time of cog budget exhaustion.

As has been emphasized, the simulation runs were made with a population of relatively high demand rate items. Consequently, the numerical results given in Section 4 should be taken as indicative rather than absolute. The output of this study has been the development of the means to quantify the effects of inventory record errors on supply operations. With a somewhat larger, random sample of items, the costs and effects of present error rates can be estimated. Proposals for reducing present error rates, by more frequent physical inventories for example, can be evaluated in terms of their cost and the improvement realized in inventory operations.

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